JPRS 75046

31 January 1980

Japan Report

No. 91

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. JPRS 75046	2.	3. Recipient's Accession No

4. Title and Subtitle	5. Report Date
JAPAN REPORT, No. 91	31 January 1980
	6.
7. Author(s)	8. Performing Organization Rept. No
9. Performing Organization Name and Address Joint Publications Research Service 1000 North Glebe Road Arlington, Virginia 22201	10. Project/Task/Work Unit No.
	11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address As above	13. Type of Report & Period Covered
	14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This serial report contains press and radio coverage on political, sociological, economic, military, and scientific and technological developments.

17. Document Analysis a. Descriptors

JAPAN
Political
Sociological
Military
Economic
Science and Technology

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group 5C, 5D, 5K, 15C, 16D, 18I, 19F, 22B

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited Availability Sold by NTIS Springfield, Virginia 22161	UNCLASSIFIED	39
	20. Security Class (This Page) UNCLASSIFIED	22. Price

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

JPRS 75046

31 January 1980

JAPAN REPORT

No. 91

CONTENTS PAGE

SCIENCE AND TECHNOLOGY

 [III - ASIA - 111]

MACHINE HEALTH MONITORING SYSTEM FOR ROTATING MACHINERY

Tokyo SHIN GIJUTSU KAIHATSU REPOTO in Japanese No 1, 1979 pp 69-79

[Article by Kazuhiro Shiraki, Nao Uemura and Yoshishige Kadoya of Mitsubishi Heavy Industries]

[Text] 1. Preface

Failures of machinery which are the constituent elements of a large plant, not only result in great economic loss due to the suspension of operation but also are undesirable from the point of safety. Because of these reasons, important machinery and equipment are daily checked or regularly inspected for maintenance and care. Nevertheless, insufficient daily checks may overlook slight damages on components and lead to major trouble, causing an inevitable abrupt suspension of operation, or there may be occasions where it will not only be economically unreasonable to disassemble and check a smoothly running machine but also an imperfect reassembly or resetting of the machine may lead to abnormalities. Consequently, the health of the machinery should be cared for properly all the time, and unnecessary opening and checking of a healthy machine should be avoided. Also, it is required, instead of examining a machine impulsively after it fails, to inspect the machine as soon as possible at the initial stage when a symptom of abnormal health appears and to repair the damage at a selected time when the plant will be least affected for the improvement of the operational efficiency of the plant. Usually, an abnormality in rotating machinery is manifested as a vibration, and therefore it is effective to diagnose it by primarily monitoring vibrations.

2. Classification of Abnormal Vibrations Generated by Machinery

Abnormal vibrations are classified by factors as in Table 1[1]. Since abnormal phenomena associated with each individual machine are different, the range of monitoring can be narrowed down, for instance, by grouping typical trouble cases for each type of machine as shown in Table 2.[2]

3. Function of Machine Diagnostic System

To diagnose a machine, it is necessary to concentrate the comprehensive information relating to the characteristics of the machine, operational information, analysis of the destruction structure, allowable limits, etc. This system is a total diagnostic system based upon vibration engineering theory and the clinical theoretical empirical engineering pertaining to the vibration troubles, and exercises the following principal diagnostic functions.

(a) Diagnostic Method by Band of Vibration

Frequencies of abnormal vibrations generated differ depending upon the causes. It is therefore possible to discriminate in general the causes of the vibrations if the abnormal vibrations are classified into vibrations in the low cycle region, vibrations in the intermediate and high cycle region and vibrations in the sound region as indicated in Figure 1.

(b) Score Diagnostic Method by Frequencies

In this diagnostic method, the relationship between the cause of the vibration and the generated frequency is expressed by a matrix, and the abnormalities are diagnosed by giving a weight coefficient to a frequency component relative to the particularly closely related cause of the vibration. As seen in Table 3, almost all abnormal phenomena are included, and the method is characterized by the ability to conduct a comprehensive diagnosis of abnormalities.

(c) Diagnostic Method by Wave Forms Phenomena

In this method, abnormalities are diagnosed by the characteristics of the wave form of the vibrations corresponding to the abnormalities, and it is effective to discriminate oil whip and flaws and damages in ball bearings, etc. Figure 2 shows an example of discriminating an oil whip and a 1/2 subharmonic.

(d) Diagnostic Method by Spectrum Analysis

By plotting frequencies on the transverse axis and frequency components on the longitudinal axis, the abnormalities are diagnosed by the changes in spectra. If the revolution degree ratio is plotted on the traverse axis instead of the frequency, abnormalities can be seen more plainly since the spectrum on the traverse axis does not change in association with the changes of frequency. For the limit value of the spectra, spectra during normal operation of single or multiple units of the same type of machine are pursued upon taking into consideration the characteristics of the machine. The limit value is then determined separately for each frequency band from the envelope of these spectra as seen in Figure 3. Also, the accuracy of the diagnosis can be improved by studying in parallel the hourly changes of this spectrum as in Figure 4.

4. Back-up Systems for Diagnosing Abnormalities

In order to diagnose abnormalities, comprehensive and proper data including information besides the results of the vibration analysis is required.

This system is equipped with back-up systems such as below so that the diagnostic accuracy will be enhanced.

(a) Detection of bearing load by the bearing oil pressure

(b) Detection of surging and stalling by rotation

(c) Detection of flaws on ball bearings

(d) Detection of contact of rotating bodies

5. Diagnostic System for Vibrations of Rotating Machinery

Figure 5 shows the diagnostic system equipped with the functions described in Section 3 and 4. Also, the basic make-up of the system is illustrated in Figure 6. Features of the system are as follows. During operation, vibration values, etc, are checked first to make sure that they are within the limit values. In case the vibrations abruptly increase and largely exceed the limit value, the machine is designed to trip as well as to start an automatic recording of the data for the analysis of the cause of the problem simultaneously so that the cause will be brought to light at a later time. Also, in case the vibrations gradually increase, or in case they have reached the precautionary value, increasing rate will be calculated and the operation will be stopped for safety if the increase occurred rapidly, or the problem will be diagnosed automatically based upon the diagnostic software if the increase occurred slowly. Furthermore, in case data collected under a fixed condition is not by itself enough to lead to a satisfactory diagnosis, vibration characteristics are investigated under different loads and numbers of revolutions so that the problem will be diagnosed based upon a more detailed investigation. Now, let us introduce a block and line diagram of the diagnostic system for abnormal vibrations of the turbine generator system in Figure 7. The system is composed of Pick-up (i), Surveillance and Monitor element (ii), Data Analysis and Vibration Diagnosis Element (iii) and Operation Control Element (iv). Especially, the vibration diagnosis element, the heart of the system, is concentrated with the comprehensive vibration analytical technology.

6. Postscript

Abnormalities cannot be diagnosed effectively without technical understanding and experience. With this in mind, the efficiency of surveillance has been improved by narrowing down the target items to be monitored and by designing a system which can monitor each individual machine systematically. We are hoping to see this system used efficiently and to contribute to the improvement of the reliability of machinery and plants.

Table 1. Factors of Vibration Troubles[1)]

Fields		Factors	Phenomenon	
	1.	lack of investigation during designing	a.	forced vibration
	2.	bad structural design	b.	resonance
	3.	bad system design	c.	selective resonance
I. Design and plan	4.	lack of rigidity and strength	d.	whirling speed
	5.	cutting corners and expenses	e.	self-exciting vibration
	6.	ex post facto problems to be controlled	f.	oil whip, fluid whip, steam whi
	7.	unpredictable problems at the present time	g.	surging, flutter
	8.	specific problems	h.	swirl and spiral resonance
	9.	errors, drawing errors	i.	air column resonance
II. Manufacturing and processing	10.	inferior accuracy, insufficient performance	j.	turbulence, friction, cavitatio
	11.	faulty installation, clamping and shrinkage fitting	k.	impact wave, impact
	12.	non-uniformal thickness, eccentricity	l.	beat
	13.	bad setting and adjustment	m.	non-linear resonance
	14.	operational and adjusting errors	n.	subharmonic resonance
	15.	no operational inertia	o.	harmonic resonance
	16.	intrustion of foreign matter	p.	parametric severe vibration
III. Installation, adjustment and operation	17.	contact, deformation, overstrain, strech	q.	stick, slip
	18.	improper centering	r.	unbalance, vibration
	19.	improper balancing	s.	thermal unbalance
	20.	insufficient flushing, improper lubrication	t.	noise, strange sound
	21.	insufficient warming-up and preliminary adjustment	u.	vibration propagation
	22.	sinking foundation	v.	abnormal vibration
IV. Aging, maintenance	23.	basic and structural delinquency	w.	
	24.	abrasion, extinction, deformation	x.	
	25.	chemical and material degeneration & change	y.	no problem
	26.	improper maintenance		
	27.	pollution, earthwuake		
V. Others	28.			
	29.			
	30.	unknown causes, others		

Table 2. Classification of Vibrations by Causes[2)]

	Pump		Ventilator		Electric motor	
Internal abrasion	7 cases	18%	8 cases	30%	7 cases	19%
Internal corrosion	0	-	1	4	0	-
Internal cracks, slack	3	8	2	8	5	13
Bearing abrasion and bracks	0	-	3	11	3	8
Poor lubrication	3	8	2	8	4	10
Setting condition changes, improper	14	36	7	27	6	16
Base changes, improper	1	2	1	4	4	10
Picking-up of foreign matter, adhesion	5	13	1	4	0	-
Others	6	15	1	4	9	24
Total	39	100	26	100	38	100

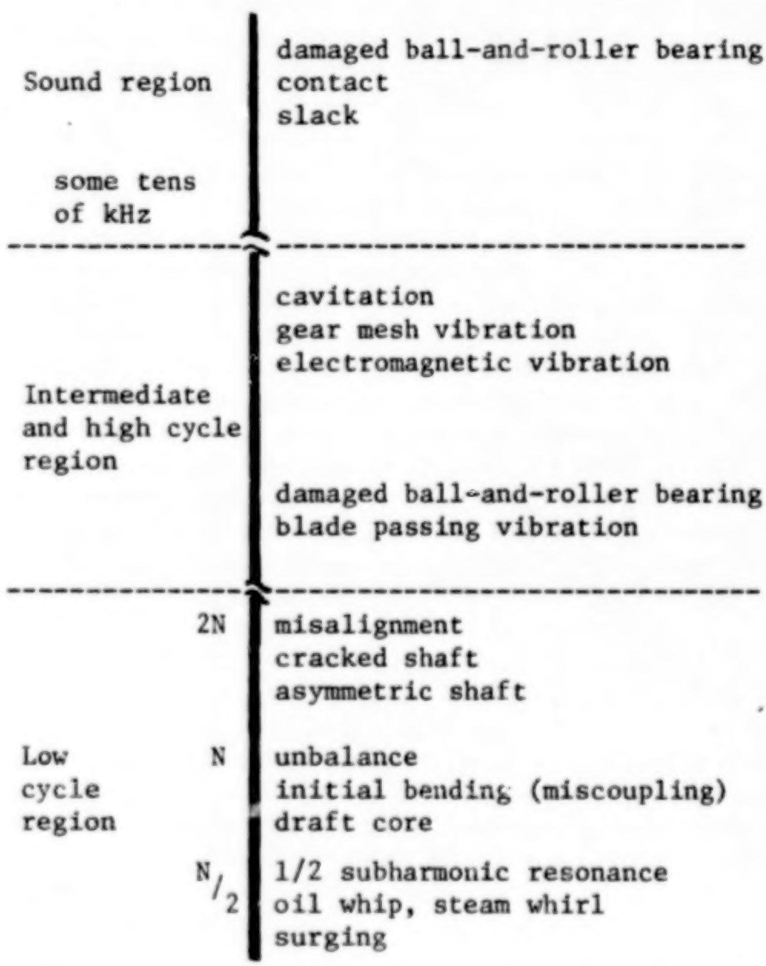


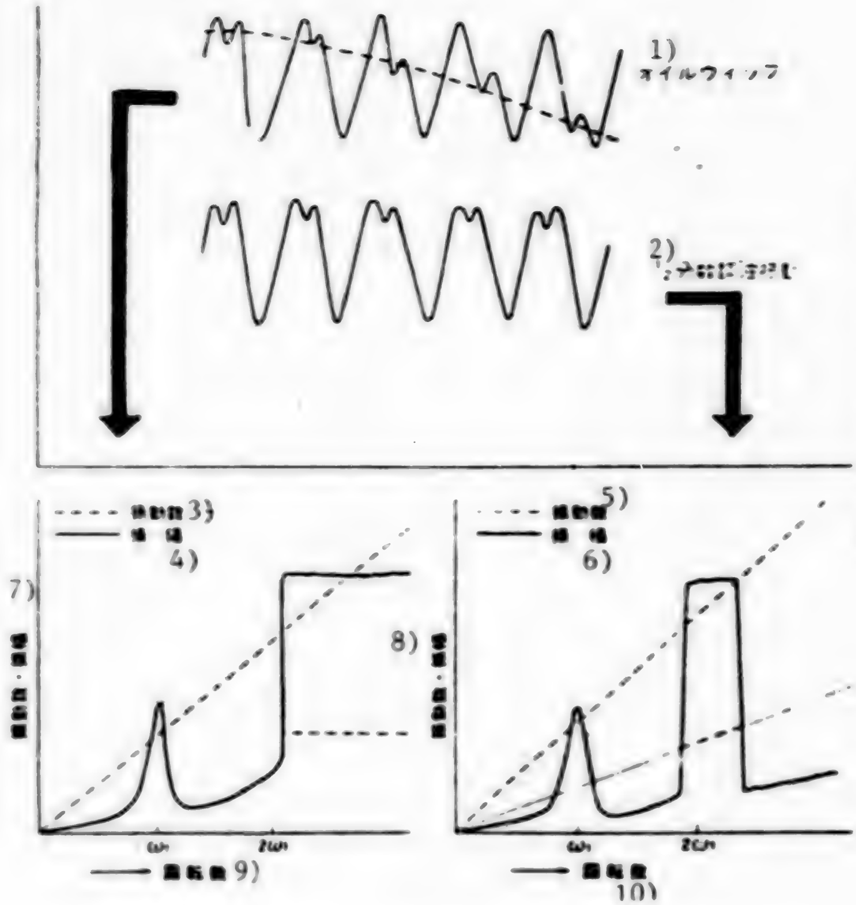
Figure 1. Band of Frequency and Diagnosis of Vibration

Table 3. Eminent Frequencies and Related Causes of Vibrations

1) 現象 / 3) 原因	2) 振動数成分																
	低周波振動 4)	0.3 ~ 0.49 fn	1/2 fn	0.51 ~ 0.99 fn	回転成分 fn 5)	2 fn	3 fn	高次 fn 6)	fnZ	軸危険速度 fc1 7)	2次 fc2 8)	3次 fc3 9)	メッシュ振動数 fc 10)	2fc	3fc	音響域振動 11)		
12) ころがり軸受損傷																***		
13) 接触	*	*	*	*	*					*	*	*				***		
14) クラック					***	***	*	*								*		
15) キャビテーション																***		
16) ギヤ損傷													***	*	*	**		
17) 電磁振動																***		
18) 翼振動									***									
19) ミスアライメント					**	**	*	*										
20) 非対称軸						***												
21) アンバランス					***													
22) 初期曲り					***													
23) ドラフトコア		***														*		
24) ガタ・非線形		*	**	*	*	*	*	*										
25) オイルホイップ		***																
26) スチームホワール		***																
27) サージング	***																	

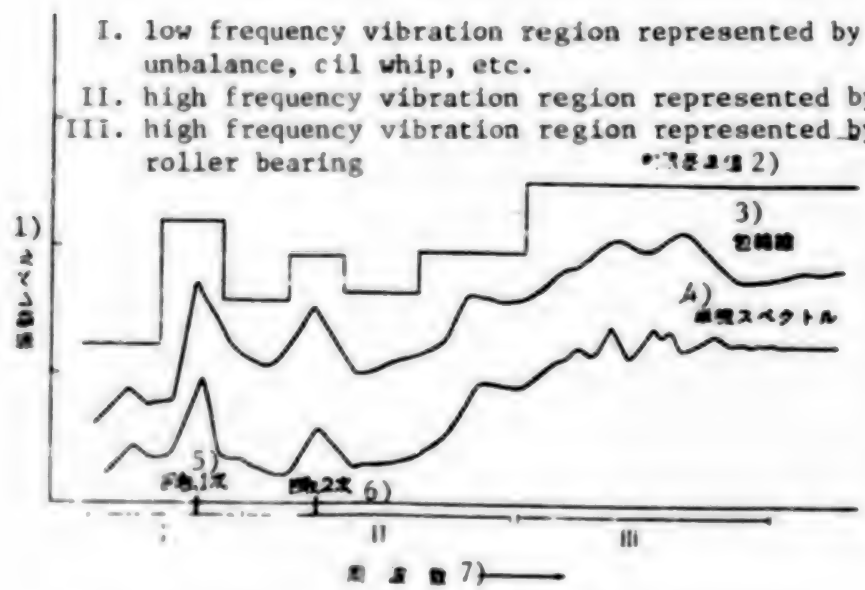
Key:

1. phenomena
2. frequency components
3. causes
4. low frequency vibrations
5. rotating components
6. higher degrees
7. primary whirling speed of shaft
8. secondary
9. tertial
10. gear mesh frequency
11. sound region vibrations
12. damaged ball-and-roller bearing
13. contact
14. cracked shaft
15. cavitation
16. damaged gear
17. electromagnetic vibrations
18. vibration of blades
19. misalignment
20. asymmetric shaft
21. unbalance
22. initial bent
23. draft core
24. gutter, nonlinear shape
25. oil whip
26. steam whirl
27. surging



Key:
1. oil whip
2. 1/2 subharmonic vibration
3. frequency
4. amplitude
5. frequency
6. amplitude
7. frequency, amplitude
8. frequency/amplitude
9. number of revolution
10. number of revolution

Figure 2. Oil Whip and 1/2 Subharmonic Vibration



Key:
1. vibration level
2. limit standard value
3. envelope
4. spectrum of a single machine
5. rotation, primary
6. rotation, secondary
7. frequency

Figure 3. Establishment of Enveloping Spectrum

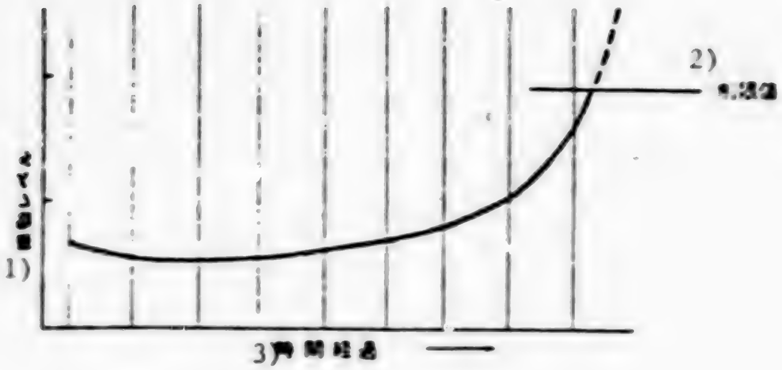


Figure 4. Hourly Changes of Vibrations

Key:
1. vibration level
2. limit value
3. course of time

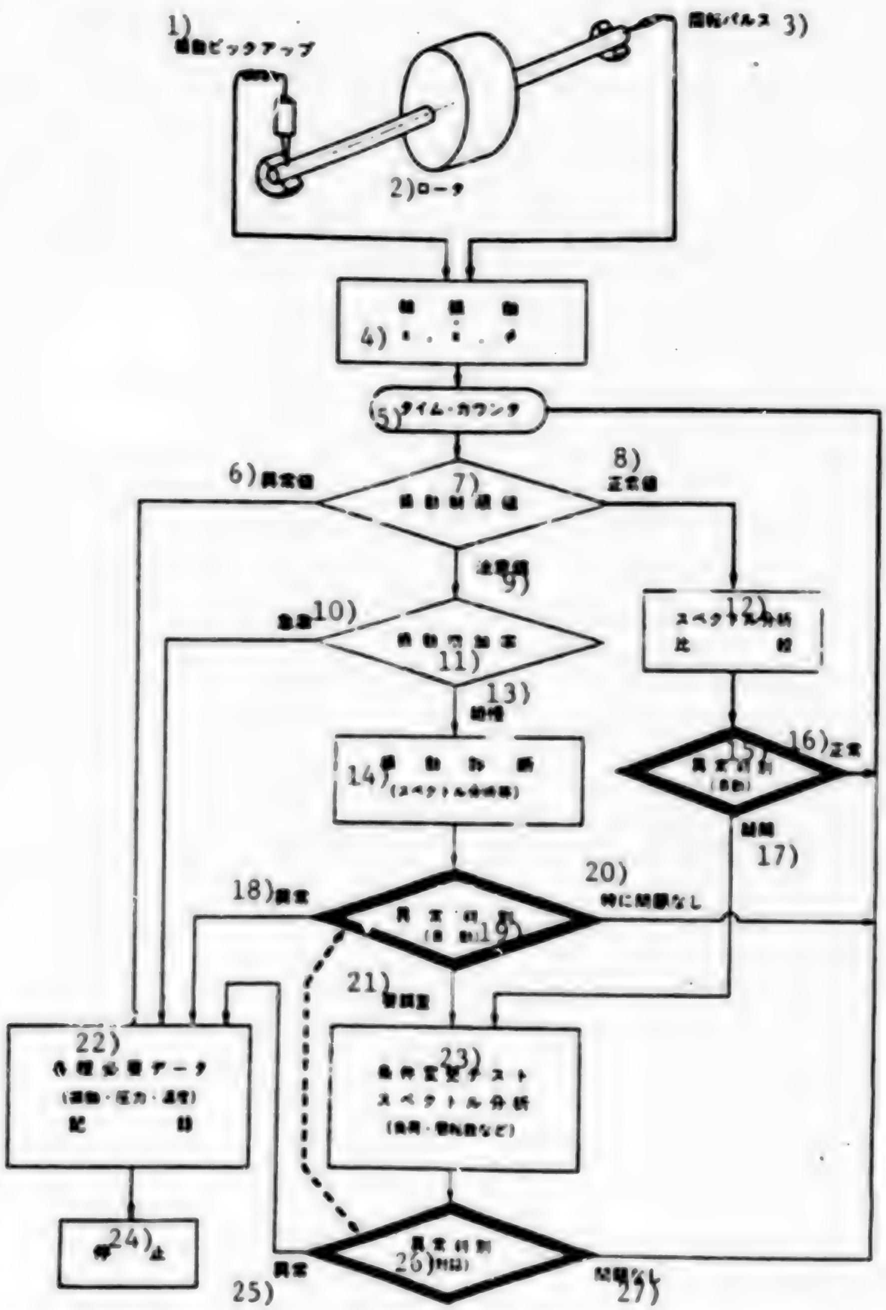


Figure 6. Vibration Diagnostic System for Rotating Machinery

[key on following page]

[Key to Figure 6]

1. vibration pick-up
2. rotor
3. rotary pulse
4. axial vibration
5. time counter
6. abnormal value
7. vibration limit value
8. normal value
9. precautional value
10. sudden increase
11. vibration increasing rate
12. spectrum analysis comparison
13. slow
14. vibration diagnosis (spectrum analysis and others)
15. discrimination of abnormality (automatic)
16. normal
17. suspect
18. abnormal
19. discrimination of abnormality (automatic)
20. no special problems
21. need investigation
22. recording of various data required (vibration, pressure temperature)
23. spectrum analysis with altered test conditions (load and number of revolutions, etc)
24. suspension
25. abnormal
26. discrimination of abnormality (discussion)
27. no problems

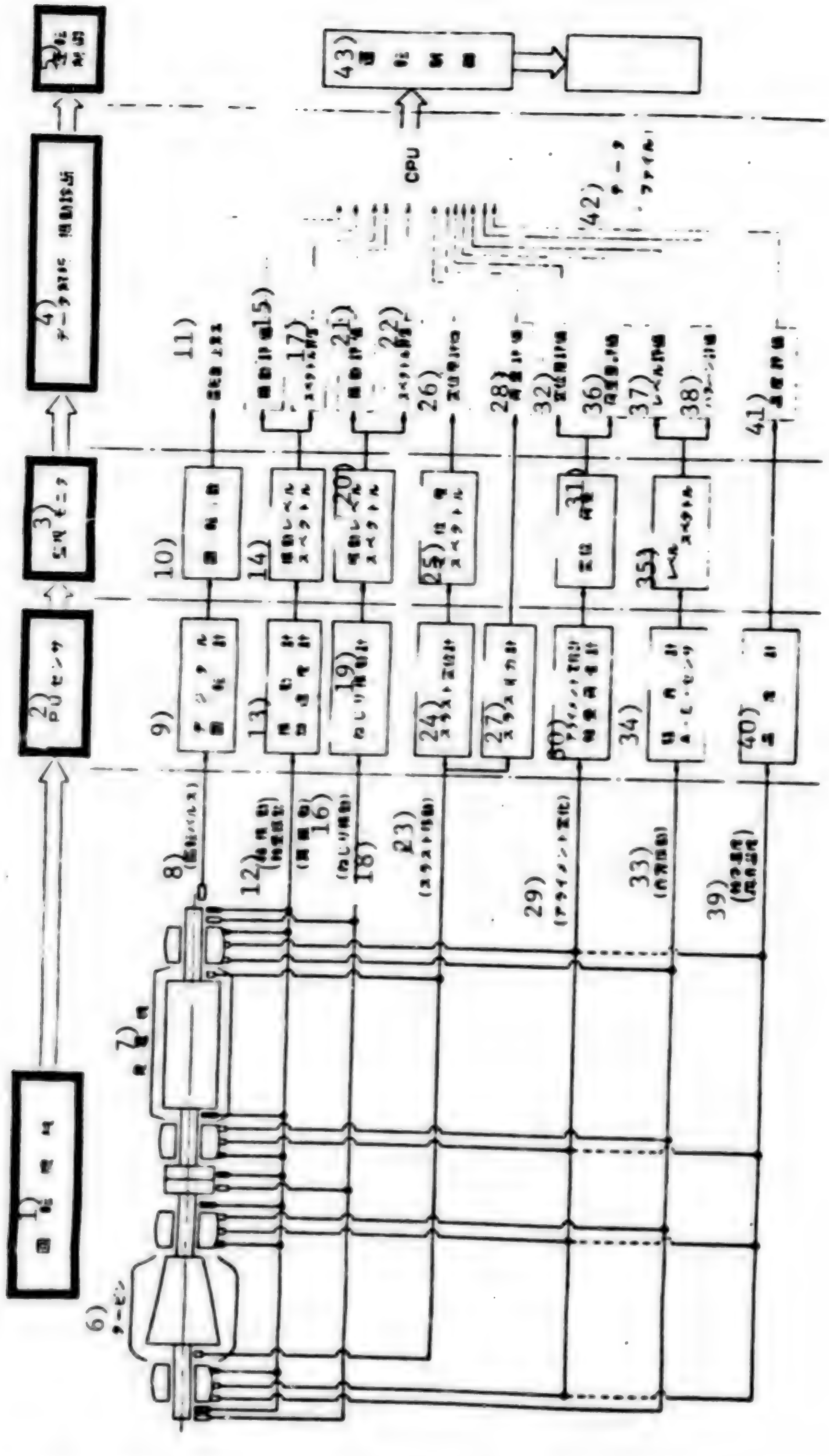


Figure 7. Abnormality Diagnostic System by Vibrations of Rotating Machinery

[Key on following page]

[Key to Figure 7]

1. rotating machine
2. P.U. sensor
3. surveillance, monitor
4. data analysis, vibration diagnosis
5. operation control
6. turbine
7. generator
8. rotary pulse
9. digital tachometer
10. number of revolution
11. rate of increase in the number of revolutions
12. axial vibration, bearing vibration
13. vibrometer, accelerometer
14. vibration level spectrum
15. vibration evaluation
16. blade evaluation
17. spectrum evaluation
18. torsional vibration
19. torsional vibrometer
20. vibration level spectrum
21. vibration evaluation
22. spectrum evaluation
23. shifting of thrust
24. thrust displacement gage
25. displacement spectrum
26. displacement evaluation
27. thrust force gage
28. load evaluation
29. changes in alignment
30. alignment displacement gage, bearing load meter
31. displacement/load
32. displacement evaluation
33. sound vibration
34. sound level meter, A.E. sensor
35. level spectrum
36. load evaluation
37. level evaluation
38. pattern evaluation
39. bearing temperature, lubrication temperature
40. thermometer
41. temperature evaluation
42. data file
43. operation control

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2) Investigation Committee Report, KARYOKI HATSUDEN Vol 22, No 11.

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CSO: 8129/0468

CONDITIONS FOR UPGRADING ELECTRIC VEHICLE RELIABILITY SURVEYED

Tokyo MOTOR MATERIAL in Japanese Aug 79 pp 39-50

[Article by the Japan Electric Vehicle Association]

[Text] Introduction

This survey report is a compilation of the "Survey on Conditions for Upgrading Electric Vehicle Reliability" conducted by the Japan Electric Vehicle Association under a contract from the Ministry of International Trade and Industry as one phase of the "Survey on Conditions for Popularizing Electric Automobiles" conducted by the ministry for JFY 1978.

This survey was compiled with the cooperation of the various people associated with the Japan Electric Vehicle Association Inc. and the Electric Automobile Reliability Survey Committee.

Makeup of the Electric Automobile Reliability Survey Committee

Principal Investigator	Kanji Yada	Mechanical Engineering Laboratory, Agency of Industrial Science and Technology
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	Norio Nakatani	Daihatsu Kogyo Co., Ltd.
	Naoki Danno	Toyo Kogyo Co., Ltd.
	Hiroshi Nagahara	Nissan Motor Co., Ltd.
	Hirotaka Ota	Mitsubishi Jidosha Baibai Co., Ltd.
	Osamu Maekawa	Japan Storage Battery Co., Ltd.
	Takeshi Matsuo	Hitachi, Ltd.

1. Preliminary Statements

The electric automobile offers some advantageous features over the conventional internal combustion engine powered automobile with regard to its low degree of pollution and energy conservation aspects, but the factors which stand in the

way of its greater use are thought to be the price and the limited cruising range. If it were possible to bring down this cost and reduce the factors which limit exploitation of the features of the electric automobile, the constraints to the greater use of electric automobiles will be eased considerably.

In another direction, an electric automobile uses a battery as its power source as a result of which accidents and troubles are considerably different from those associated with internal combustion engine automobiles, as can be expected. In addition, the present automobile user is accustomed to handling internal combustion engines, and there may be some feeling of unfamiliarity or lack of trust with this different type of vehicle. If there is negligence in creating awareness on the part of these users with regard to the electric automobile, the impression of the electric automobile may suffer, and this may be a factor that will hinder the popular acceptance of electric automobiles. That is why there is need to survey the actual situation with regard to accidents and troubles incurred by electric automobiles, propose necessary countermeasures, increase their reliability, and provide guidelines to avoid mistaken handling on the part of users.

This research was initially directed at actual surveys on accidents and troubles, but the small number of electric automobiles used in this country made available only a limited amount data and it was necessary to supplement it with data obtained from other countries. At the same time, there was no recourse but to depend on examples of the past, such that there was the possibility that minor accidents and accidents which do not detract from further vehicle use might not be incorporated into the data file. In this manner it was difficult to investigate the factors responsible for the many different types of accidents.

As a result, accidents which conceivably could occur to electric automobiles were set up, and their causative factors as well as probability of occurrence were analyzed and used to augment the aforementioned list of causative factors. An automobile itself possesses inherent dangers, and here cognizance was taken of the fact that this was an electric automobile, so that the following items thought to be characteristic of electric automobile accidents and troubles were taken into consideration.

a) Induced explosion
b) Electric shocks
c) Erratic running
d) Fire
e) Running abnormalities (includes inoperable condition)
f) Injury to passenger or third party
g) Others

Respective countermeasures have been devised for the accidents and troubles of the types listed above, so it is not the case that these electric automobiles have a high probability of being involved in these types of accidents.

Consequently, should the electric automobile of the future be involved in some well defined accident or trouble situation, they will not occur singly but are expected to occur in a composite state of these various conceivable cases. On the other hand, it is very difficult to predict such events, and this study cannot extend itself into their resolution.

The discussion above emphasized the hardware aspects with regard to accidents and damages and the countermeasures which the vehicle manufacturers devised to guard against such events. Next, the points to be considered by which the user or service man's mistakes would not cause such events, in other words, countermeasures against the software aspects, have been included to serve as technological guidelines for the different types of accidents.

2. Actual Examples of Accidents and Damages to Electric Automobiles

2.1 Expository Comment

The accidents and damages associated with electric automobiles when compared to the internal combustion engine automobile have some features unique to electric automobiles because the electric automobile motor, control mechanism, battery, and charger replace the internal combustion engine and the fuel tank. On the other hand, there are features which are common to both.

The examples to be taken up here are limited mainly to those unique to electric automobiles which were drawn from the results of 83 questionaire replies from electric automobile users as of the end of 1978 (Electric Automobile Use Monitoring Survey Report-S, March 1979) (see Fig 1) and examples from the Nagatano Industrial Development (Electric Automobile Running Mode Suitability Survey Report-S, March 1978(see Table 1). They include examples taken from the maker's production and testing stage to direct claims on the part of users as well as examples which technicians at electric automobile service stations submitted.

Examples from other countries include accidents with the American Battoronic Minivan (State of the Art Assessment of Electric and Hybrid Vehicle, January 1978, NASA Lewis Research Center) (see Table 2) and the accidents and damages reported by the British Lucas Batteries, Ltd. (some Aspects of Electric Vehicle Safety, Oct 1978, G.G. Harding, Lucas Batteries, Ltd.) which were included to provide reference material for future electric automobile reliability.

The following classification according to degree of importance was adopted in classifying the accidents and damages.

1) Those which had the potential of affecting human life
2) Those which did not involve human fatality but which completely wiped out vehicle usefulness
3) Those which did not impair vehicle running but impaired some aspect of vehicle capability

There was also the classification according to chassis, motor, control mechanism, battery, charger, and accessory equipment.

2.2 Outline of Survey Results

2.2.1 Outline of Accidents and Damages According to Degree of Importance

Since the electric automobile itself has not won acceptance in the general market, it may be that its average speed will be considerably smaller than that of the internal combustion engine automobile, and there are no examples in the present survey which take in accidents involving people injured by moving vehicles. On the other hand, there was the report of an accident in which a battery ruptured during the course of charging, which is a method of energy replenishment unique to the electric automobile, and this is a representative example of an accident which can affect human life.

An example of a mishap in which no human injury effect was seen but which caused damage to the vehicle of a degree sufficient to incapacitate the vehicle is one in which maladjustment of the control system made the vehicle unusable or one in which battery problems put the automobile out of commission.

While there is not much effect as far as its performance as an automobile is concerned, there were a large number of minor troubles at various spots and minor troubles experienced during recharging. There was a large number of troubles particularly with auxiliary equipment.

2.2.2 Outline of Accidents and Troubles According to Part

When the accidents and troubles to electric automobiles were investigated according to the example of the Nagatano development. In the example of the American electric automobiles such as the Battoronic Minivan case compiled by NASA's Lewis Research Center of the United States, troubles involving the control equipment were the most numerous among those reported.

The motor itself was not much of a source of trouble either in Japan and in the United States, and the number of troubles associated with the motor was extremely small.

There was a fairly large number of troubles reported of a charging equipment related nature, and these included those related to the charger itself and those tied in with the charging socket plug. A problem of secondary nature tied in with the charger was overcharging of the battery, which accounted for a number of cases.

Automobile related troubles included those tied in with the power transmission system, steering system, brake system, and chassis, and these troubles were similar to those experienced with the usual internal combustion engine automobile. Consequently, the replacement and maintenance of parts during periodic inspections at a maintenance plant did not come under the classification of troubles, and only those troubles which the technician at an electric automobile service station indicated as troubles were handled.

2.3 Actual Examples of Accidents and Troubles

2.3.1 Actual Examples of Accidents and Troubles Classed According to Degree of Importance

1) Those with potential of affecting human life

While charging the battery of a car, the user heard an unusual sound from the battery, cut off the switch, and then after resuming charging removed the battery cover to make an inspection, whereupon the battery exploded. One such example was reported from the entire country. The suspected cause for this incident was:

a) The battery conductors had corroded badly from long use.
b) The connection where corrosion had progressed the most broke and the charging current generated sparks.
c) The battery was completely charged and being subjected to further charge resulted in a large accumulation of gas, which was set off by the sparks.
d) The ignited gas passed through the water fill tubes and damaged the covers of a group of 5 cells along with a section of the battery case. The other group of cells was not affected.
e) Since the battery cover had been removed, the explosion scattered pieces all around.

2) Troubles in which vehicle capabilities were lost

Immobilizing incidents were the most numerous among the monitor survey results. These were associated with a number of causes, and they were difficult to pin-point. A clearly established source of trouble is one relating to a test produced vehicle in which trouble occurred in the DC-DC converter such that the vehicle would not move and the horn would not sound. This is possibly a representative example.

In this particular case the heat discharge of the transformer was poor while the control section was faulty, both of which were tied in to the trouble, and this situation was remedied by altering the converter box shape and the internal parts layout. This type of trouble also appears in the American list. In the American example the trouble assigned to the converter which induced overcharging of the auxiliary battery. This was remedied by replacing the converter and the auxiliary battery.

In addition, there are examples in which the vehicle could not be moved because of a main fuse blowout. This was not much of an incident as far as troubles go, but this probably can be classed as a major setback to vehicle capability. Various types of cases were reported with regard to fuse blowouts. The examples reported from the Nagatano development include fuse failure due to loosening of a battery terminal. The examples of the United States include a number of cases in which 300 ampere fuses went out when the vehicles were climbing hills at top speed.

There also were cases in which cracks in the battery case and leakage of liquid from the gas escape ports caused enhanced corrosion of the battery terminals so that poor contact made the car immobile even when the battery was fully charged. These examples included cases in which the vehicle in question was a test produced automobile, and reinforcing the battery case (thickening the walls and installing ribs) and the use of a one time liquid filling device to eliminate the gas escape port remedied the situation.

3) Example in which part of the functions were lost

In the examples from the Nagatano Industrial Development there were many trouble incidents of overdischarge of auxiliary batteries because someone forgot to turn off the key switch, inadequate running distance for the vehicle resulting from the use of a gasoline engine generator in charging the auxiliary battery, overdischarging of the auxiliary battery because of lack of idling, and blowout of the auxiliary circuit fuse.

Among the charger related troubles were arcing burnout of the socket plug, breakdown of insulation on the charging lead wire causing short-circuiting, and blowout of the fuse in the charging circuit.

The examples from the United States include failure of the residual charge gage and faulty function of the residual charge gage even when it worked. In addition, there were many cases in which the connector wire to the charger burned out just as in the Japanese cases.

2.3.2 Examples of Accidents and Troubles According to Location on Vehicle

1) Chassis

Among the specific examples of chassis related troubles which are particularly inherent to the electric automobile were the clutch related troubles, which were rather common. Caused by strong shocks when starting off, there involve the headache of frequent clutch replacements. At the same time, clutch slipping can cause a loss in speed. There are also examples in which the shock at starting off caused structural members to break and cracks to form in the body.

The problem of corrosion to the body is also unique to the electric automobile, and there are examples in which battery gas generation has caused corrosion to the undercarriage.

Heat discharged from the brakes causing overheating of the battery has been cited as one type of trouble encountered in the United States, and this situation has been countered by relocating the battery further away from the brakes or by the installation of heat shielding plates between the battery and the brakes.

In addition, there are many cases of tire wear and brake system wear requiring frequent maintenance efforts.

2) Motor and control equipment

Where the motor is concerned, the chief complaints seem to be the odd sounds that come forth during hill climbing, and actual troubles from the motor itself were not found in this present survey.

There were many troubles with the control equipment. These included breakage in the wire of the mechanism operated by the accelerator pedal making driving out of the question and burnup of the base plate element of the subcontroller making the main switch inoperable, along with burnout of the control equipment fuse making the car inoperable.

In addition, there were troubles with the connector terminals of the ON-OFF switch of the main circuit, troubles with the auxiliary relay, life of parts used very frequently, and troubles associated with the manner in which the operator used the vehicle. Among the accidents associated with faulty operation were misconnection of the power battery which burned out parts of the control mechanism, and this has been counteracted by the installation of a diode to guard against reverse flow currents in the control mechanism.

Commutative loss of the chopper (erratic operation of the th[illegible] making current shielding no longer possible) has been a type of trouble that appears not too infrequently. Since this type does not often recur, a no-fuse breaker has been installed to insure safety.

3) Battery

Troubles arising from the battery include frequent replenishment of electrolyte required near the end of the life of the battery, rapid loss in capacity of the main battery which cuts down on vehicle speed, and other problems directly attributable to the performance of the battery itself.

In addition, there were the troubles arising from corroded battery terminals which caused immobility, loosening of the battery terminals resulting in damaged leads, and blown out battery main fuse, and other structurally related sources of trouble.

The American examples did not contain many examples in which the battery failed before their normal time, but the number of trouble incidents increased sharply as the end of their regular life was approached in the pattern observed there.

In addition, there were reported in this country an incident of ignition of the gases accumulated in the battery when the battery was being charged. This type of accident was rather scarce in other countries, and only a single incident was reported in 1976 in the United Kingdom by the Lucas Company.

4) Charger

Among the accidents and troubles associated with the charger are those stemming directly from the charger itself, such as the faulty operation of the switch to activate the charger, necessitating replacement or repair, and a blown out fuse in the charging circuit.

Among the troubles arising from the charging socket plug are those in which plug arching caused burns and insulation deterioration with time in the charger leads, eventually causing short circuits.

Some secondary troubles arising from the charger were improper operation of the converter, which made impossible simultaneous charging of the main and auxiliary batteries. There were cases in which the auxiliary battery was charged more, and also cases in which there was overcharging from the auxiliary battery.

The American examples also include several cases of secondary troubles arising from the charger, and countermeasures such as the installation of a timer to prevent battery overcharging have been introduced.

5) Accessory equipment

Troubles with accessory equipment that involved the electrical circuits to the horn, wiper, and lights powered by the auxiliary battery and troubles with the speedometer, residual charge gage, and ammeter gage have occured.

The frequency of these accessory equipment related troubles is rather large compared to the other types of troubles, and most such troubles arise from overdischarging of the auxiliary battery. Unlike the gasoline automobile, the range of an electric automobile is generally short and there is little idling, so the use of a gasoline engine generator to charge the auxiliary battery results in insufficient charge.

Furthermore, an electric automobile at rest makes very little sound, as a result of which it is very easy to forget to turn off the key switch. This too is one factor responsible for overdischarge.

Where instruments are concerned, lack of precision of the residual charge gage is a frequent source of trouble, and there are many opinions stating the need for precision equal to that of a gasoline automobile fuel gage.

Reliable operation of the residual charge gage is also a problem in the United States, and many examples were cited in which the gage was immediately replaced. This is one of the major source of trouble along with the overdischarge of the auxiliary battery which have been cited as major problems.

3. Conceivable Accidents and Troubles and Their Countermeasures

3.1 Induced Explosion

3.1.1 Expository Comment

High energy density batteries have been developed operating in a number of modes as the power source, and this present survey was directed at the widely used lead storage battery (hereafter simply referred to as "battery").

At the end of its recharging cycle, the water in the electrolyte undergoes electrolysis to produce hydrogen and oxygen gases. This electrolytic decomposition of water takes place proportional to (charge-discharge capacity) in accordance with Faraday's law, and 0.366 cc water is lost per 1 Ah. At the same time, 1 Ah overcharge generates 0.42 liter hydrogen and 0.21 liter oxygen (0°C, 1 atmosphere pressure) thereby creating an atmosphere ripe for induced explosions. This necessitates adequate consideration against spark generation. This is why it is necessary to properly insulate battery terminals, prevent leaks, and install explosion proof equipment to provide safety measures designed to improve relaibility. The factors responsible for these induced explosions along with their countermeasures are discussed below.

3.1.2 Induced Explosions Arising From Battery Life and Deterioration

1) Those due to deterioration of battery plates and conductor section

A battery uses dilute sulfuric acid as electrolyte, and the electrochemical reaction causes corrosion to proceed with the passage of time. In addition, repeated discharges and recharges cause deterioration of the constitutive parts. As a result, the following sources of sparks which can ignite explosions are created.

a) Because of capacity differential at the end of its life, a battery which is in an advanced stage of deterioration suffers from lack of fluid, which eventually results in a break in the current pathway and gives rise to a potential spark source for inducing explosion.

b) Advanced corrosion of connecting leads results in a circuit break which can generate sparks in part of the discharge or recharge circuit.

c) Sulfuric acid is dropped on the battery terminals during normal maintenance--such as a check for electrolyte density or temperature measurement--which corrodes the terminals and create a source of spark generation.

2) Explosions due to battery case, cover, etc.

a) A battery case is made of thermoplastic resin (such as polypropylene), and cracks formed from thermal deformation during use and impacts and vibrations result in leaks which are sources of sparks.

b) Improper closure of battery cases and cover and pinholes cause leaks between single cells which eventually result in lack of fluid and deterioration leading to induced explosions.

3.1.3 Induced Explosions From Deterioration of Parts Making Up the Battery

1) Explosions due to improper or deteriorated battery connections

a) Loosening of a terminal because of failure to install a spring seat washer or lack of capacity of the terminal section causes sealing-in of heat generated and generation of sparks.

b) Lack of a cover over the terminal section results in external circuit sparks.

2) Explosions due to improper battery containment

a) Gas discharged from the battery accumulates in the battery enclosure, and an explosion is caused by a spark set off by a burning fuse or other incident.

b) Improper mounting of battery results in damage to battery case or terminals which then generate sparks to set off an explosion.

c) High voltage is generated between adjacent terminals, and leaks from this voltage set off explosions.

d) Freezing of moisture in the filter during winter seals in discharge gas.

3.1.4 Induced Explosions Resulting From Conditions of Use

Spark formation resulting from an abnormal temperature rise due to large current discharge and breaks in the connecting sections.

3.1.5 Induced Explosions Due to Inadequacies of Charger

1) Those due to overcharging and rise in temperature

Troubles with relays or timer cause charging control to suffer and give rise to overcharging and a rise in temperature which cause fluid insufficiency and eventual spark generation.

2) Troubles due to deterioration of battery

Extreme deterioration of battery causes relay malfunction, thereby giving rise to overcharging and temperature rise.

3.1.6 Countermeasures Against Induced Explosions

1) Battery related countermeasures

a) Provide a standardized insulated cover to prevent direct contact of tools or human hands yet enable ready measurement of voltage and other measurements.

b) The connecting wires should be insulated or provided with a protective cover, and this practice should be adopted as standard procedure.

c) Standardization of terminals, bolts, nuts, and washers designed to guard against loosening.

d) Standardization of battery installation procedure to guard against damage to battery.

e) Improved battery cover construction to prevent troubles arising from splashing of electrolyte.

f) Specifying the voltage for battery groups to prevent shocks.

g) Development of battery construction difficult to damage, battery case material of superior heat resistance and impact resistance, and battery case structure with minimal gas accumulation space.

2) Battery accessories

a) Standardization of exhaust gas equipment to prevent explosions (performance, installation, maintenance).

b) Standardization of comprehensive gas discharge device (performance, installation, handling).

c) Improvement of alarm devices such as liquid surface sensor and temperature sensor.

3) Charger

a) Development of control and protective equipment to prevent overcharging (overall charging system).

b) Development of protective equipment to prevent battery overheating (detecting battery temperature during charging and liquid surface level).

4) Maintenance, handling

a) Providing manuals on battery handling.

b) Specifying battery replacement standards.

c) Warning signals such as caution bells.

d) Promoting safety education on handling electric automobiles (pamphlets, movies, etc.).

3.2 Shocks

3.2.1 Expository Statement

1) Causes of shocks

Shocks are also called electrical shocks, and these are incidences of physiological affect on some part of the body due to the passage of electrical current. Assuming constant resistance in a human body, there will be a large current passing through the human body the higher the contact voltage, and the danger from shock becomes even greater.

Since an electric automobile uses a battery as its power source, the voltage used is larger than what was experienced in the past. This is why inadequate insulation of the batteries and electrical parts carried on electric automobiles can result in shocks whenever a person makes contact with these parts.

2) Degree of shock

a) Degree of danger due to shock

In order to discuss the degree of shocks that can be experienced from electrical automobiles, it is necessary to know the electrical properties of the human body that used the automobile, such as the current level that can be tolerated and the level of danger that is present.

a) Resistance of the human body

The degree of danger of shock is controlled by the state of the human making contact (body resistance). It is usually the case that a man's resistance consists of the two resistances of intrabody resistance and dermal resistance with the former being estimated to be somewhere between 150-500 ohms and the latter undergoing severe changes depending on dryness of skin, contact voltage, contact area, and contact pressure.

The relationship between contact voltage and human body resistance according to (Freiberger) [phonetic] is shown in Fig. 2, and the skin moisture is used as parameter here. The current passage between the feet and hands was measured in this case.

That is to say, the resistance of the human body is lower the more moist the skin and the higher the contact voltage, and the degree of danger is accordingly higher.

b) Type of electrical source and voltage

The degree of danger from shock depends on whether the power source is AC or DC and on whether the power source voltage is high or low. According to the Electrical Engineering Handbook (1973 publication of the Electrical Society) "when DC and AC are compared, AC poses more danger at low voltages. Incidence of death from shock is very small with DC voltage of 100 V or less and AC voltage of 40 V or less."

An electric automobile normally uses DC and the voltage used for this power source is the low voltage prescribed in Section 1, Article 3 of the Electrical Equipment Technology Standards, so that the degree of danger compared to an AC current of the same voltage is somewhat less.

c) Current values

The degree of danger in the event of shock is controlled mainly by the magnitude of the electric current that flows through the body. There is ongoing research, both in this country and abroad, on determining what magnitude of current poses danger to the body, and research results based mainly on experiments with animals appear constantly.

On the other hand, experiments involving man are not readily performed because of the dangers involved. At the same time, considerable differences arise due to sex, body weight, and state of health, making it impossible to state a hard and fast rule regarding the human body. Still, the following statements generally apply.

d) Duration of electrical shock

The degree of danger from an electrical shock depends not only on the current flowing through, but at the same time, greatly depends on the duration of this shock. That is to say, when the period of shock is very short, the passage of a fairly large amount of current through a human body can be safe. The relationship between duration of shock generally found and current is shown in Fig. 3. The following explanations apply to this figure.

A) Dalbage [phonetic] ventricular fine movements limiting curve $T=(116/I)^2$ (second). Here a current passage between 0.01 second and 5.0 seconds applies.

B) Keppen [phonetic] ventricular fine movements limiting curve. Fixed at 50 mA·second.

C) The Keppen curve with a 1.67 safety factor. Fixed at 30 mA·second.

There is a low voltage circuit grounding protection standard in Japan (JEA G 8101-1971) which establishes a performance standard for leak shields used for shock prevention, and the properties of curve (C) in Fig 3 are used as the permissible current-time product.

b) Safety limits for electric automobile

A general type statement on degree of shock was described in item a), but the voltage used in an electric automobile is relatively high and the main battery stores considerable energy. As a result, while the electric automobile may be classified as being safe against shocks compared to an AC power source, there is still need for continued research against shocks and devising proper protective measures against shocks.

3) Present status

a) Legal aspects

There are the following legal standards with regard to shock prevention at the present time:

i) Storage battery for automobiles

The following regulations in the safety standards (Article 17, Item 2 (3)) for highway operated vehicles apply to the general run of automobile storage batteries.

"Storage batteries must be constructed so that they are not damaged as they are being subjected to the vibrations and impacts of a moving automobile. When a battery is transported aboard an automobile, it should be contained in a wooden case or other suitable insulating material."

b) Shield to prevent shocks

The following regulations have been stipulated as mandatory equipment current leak shields used to prevent deahts from shocks and fires from electrical current leaks associated with 100-200 V voltages used in our daily lives.

Labor Safety Health Regulation (Article 333, Item (1))

Japan Electric Equipment Industry Standard Regulation (JEM1244)

Japan Industrial Standards (JIS C8371)

Research on preventing shocks by electric automobiles is being conducted under the large project system. There is need for continued research and safety directed considerations in the future.

Some conceivable causes of shock from electric automobiles and their countermeasures are described below as one step toward further research in this area.

3.2.2 Chassis

a) Source of shocks

i) When metal parts of the chassis are used as part of the electrical circuit to drive the vehicle, dangerous levels of voltage are generated between the body and electrical parts, and there is great danger from shock.

ii) There is danger when sufficient insulation is not placed over conducting sections.

iii) When the main cable coating insulation deteriorates and there is leakage to the chassis, dangerous voltage is generated between the chassis and electrical parts, and high risk from shocks results. For example, insulation breakdown from the following causes comes to mind:

a) When the quality of the insulating coating is poor

b) When insulation is damaged through clip trouble

c) When cracks are formed in insulation of the main cable due to bending of the cable

d) When insulating coat is damaged by friction with the body or throug vibrations

e) When wires within the passenger cabin are damaged by man or mechanically damaged by other parts

f) When damage is caused by flying stones and items from the road

g) Insulation is damaged by accidents such as being pinched when the car is being jacked up

Countermeasures

i) Consider use of 2-wire circuitry for operating the automobile

ii) Make considerations to avoid direct contact with human bodies

iii) Consider the following measures against main cable insulation deterioration

a) Use good insulating material on main cable

b) Use clips of suitable shape, material, and clipping mode

c) Lay out main cable to minimize bends

d) Use appropriate clipping method and spacing to minimize friction against body and vibrations

e) Provide covers anytime installation within the car may be subject to damage

f) Pay adequate consideration to damages due to flying stones and other objects on parts to the under side of the automobile and provide covers when necessary

g) Pay attention to placement of wires so that no damage can result when the vehicle is being jacked up. Also, describe jack-up points in the operator's manual.

3.2.3 Motor

a) Causes of shock

Motor insulation damage results from the factors listed below, and a current leak to the chassis can result. This may result in dangerous voltage being generated between the chassis and electrical parts and very high risk of electrical shocks.

i) Overloaded use causes heating which burns out the insulation.

ii) Overrotation causes brushes to arc and burn insulation.

b) Countermeasures

i) Use superior heat resistant insulating material. Install overheating protection when necessary.

ii) When there is danger of overrotation, install overrotation prevention mechanism.

3.2.4 Control Devices

a) Sources of shocks

i) There is great risk from shocks when suitable insulation protection is not provided at the main cable section.

ii) When the coil is exposed and the enamel, varnish, and oxide coat type insulating material do not have sufficient machanical strength, there is great danger from shocks just as when a conducting section is exposed.

iii) When there are leaks because of the causes given below and dangerous voltage is generated between the body and electrical parts, risk of shock is very great.

a) When parts make contact with their case because of vibration and impacts

b) When there is grounding to case due to arcing of contactor

c) When insulation is deteriorated by dust and rain that penetrate the case.

b) Countermeasures

i) Place insulation on covers, etc. on the main cable connection sections and insure that conducting sections are not exposed.

ii) When the insulating materials or coils and such do not have sufficient mechanical strength, consider added protection such as covers.

iii) Consider the following countermeasures against current leakage:

a) Take into consideration density when installed so that there is no contact between parts and case due to vibrations and impacts.

b) Allow adequate contact capacity of contactors, and sufficient distance between contact point and grounding point.

c) Locate port for entrance of cooling air where rain and dust can enter with difficulty. Give case waterproof construction in line with site of installation.

3.2.5 Battery

1) Battery main body

a) Factors responsible for shock

i) When a terminal is exposed, there are times when human contact results in shock

ii) Liquid leaks can arise from causes listed below and these can become the factors responsible for current leaks to the car body:

a) The battery case has insufficient strength, and vibrations and impacts create cracks in the battery case.

b) Vibration of the main cable connected to the terminal causes leakage through the electrode post pass-through section.

c) The battery case is deformed by heat generated by charge-discharge heats and creates cracks

d) When electrolyte solution is dispersed through the inspection plug or explosion prevention gas discharge plug during charging.

b) Countermeasures

i) Introduce measures such as placing covers to prevent exposed leads.

ii) Introduce the following countermeasures to prevent current leaks:

a) Provide battery case with sufficient strength to withstand vibrations and impacts.

b) Provide electrode post and battery cover with sufficient strength and leak tight structure.

c) Provide battery case with sufficient thermal resistance.

d) Take measures to prevent leakage of electrolyte solution through inspection hole and explosion prevention gas discharge hole.

2) Accessory parts

a) Factors responsible for shock

i) Leak occurs through water replenishment pipe which then becomes the source of current leak to the car body.

ii) There are times when electrolyte solution overflows when filling water or during the charging following water replenishment.

b) Countermeasures

i) Place the water replenishment pipe where there is little chance of it being damaged by flying objects such as pebbles. Install a clip or similar means to insure the water replenishment pipe is closed.

ii) When overflow occurs, take measures to exhaust overflow replenishment water and waste water out of the vehicle safely.

3.2.6 Auxiliary Equipment

1) Electrical equipment

a) Factors responsible for shocks

i) When sufficient insulation protection is not provided electrical equipment, exposed conducting sections can be major sources of shocks.

ii) When rain or dust penetrates the inside of electrical equipment, deterioration of insulation can result, causing current leakages and high incidence of shocks.

b) Countermeasures

i) Make it a cardinal rule to install electrical equipment both inside and outside a vehicle where they are not readily touchable. When it cannot be helped that installation be at a readily touchable site, provde adequate insulation.

ii) Install electrical equipment beyond the reaches of rain and provide water-proofing structure at the site of installation.

2) Charging plug

a) Factors responsible for shocks

i) The conducting section of the charging plug is exposed.

ii) Rainwater penetrates the inside of the charging plug.

b) Countermeasures

i) Use only insulation protected charging plugs.

ii) Provide construction making rainwater entry difficult.

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Table 1. Log of Electric Automobile Accidents at Nagatano Industrial Development

(1) 車種・型式		(2) 使用先	(3) 故障回数 (4) 車体関係	(5) 電池関係	(6) 制御関係	(7) 補機関係	(8) 充電器関係	(9) 計
(10) ESV26N		B 1	1	1	1	1	1	5
		B 2	0	1	1	3	1	6
		B 3	0	0	0	0	0	0
(11)	(12) S 38 V 改	V-1	0	1	1	3	0	5
		V-2	0	2	1	3	2	8
		V-3	3	5	0	3	2	13
	E S 38 V	V-4	1	5	4	5	1	16
		V-5	1	1	2	1	0	5
	(13) S 40 V 改	V-6	0	0	0	1	0	1
(14)	E S 38 P A	P-1	0	1	0	2	1	4
		P-2	1	5	3	6	0	15
	E S 38 P B	P-3	0	2	2	1	1	6
		P-4	0	1	0	2	0	3
(15) DBC-1A		D-1	3	3	1	2	2	11
		D-2	1	0	0	1	0	2
		D-3	0	1	0	0	0	1
		D-4	0	0	0	0	0	0
(16) B-20		T-1	0	0	0	0	0	0
(17) 合計			11	29	16	34	11	101

Key:
1. type of vehicle
2. user
3. number of troubles
4. body related
5. battery related
6. motor control related
7. auxiliary equipment related
8. charger related
9. total
10. electric microbus
11. light van electric automobile
12. S 38 V modification
13. S 40 V modification
14. light truck electric automobile
15. light 3-wheel service car
16. service car
17. total

Table 2. Record of Electric Automobile Accidents in the United States

(1) 故障モード	(2) 故障記録の%			
	USPS DJ 5E	Battronic Minivan	Citycar	合(3)計
(4) 電気駆動システム	91%	63%	76%	230%
(5) 電池	15	10	7	32
(6) 制御装置	47	10	9	66
(7) 電動機	1	1	9	11
(8) 充電器	12	9	10	31
(9) 充電計	2	12	0	24
(10) 交換器	0	11	0	11
(11) その他	5	0	0	5
(12) 車両	3%	34%	24%	61%
(13) ブレーキ	0		21	
(14) ライト	1		0	
(15) 補助電池	1		3	
(16) その他	1		0	
(17) 他の故障	6%	3%	0%	9%
(18) 運転者の過失	6	0	0	6
(19) 不明	0	3	0	3
(3) 合計	100	100	100	300

Key: 1. trouble mode 2. percent of total troubles logged 3. total
4. electric drive system 5. battery 6. control equipment
7. motor 8. charger 9. charging gage 10. exchanger
11. others 12. vehicle 13. brake 14. lights
15. auxiliary battery 16. others 17. other troubles
18. operator's excesses 19. unknown

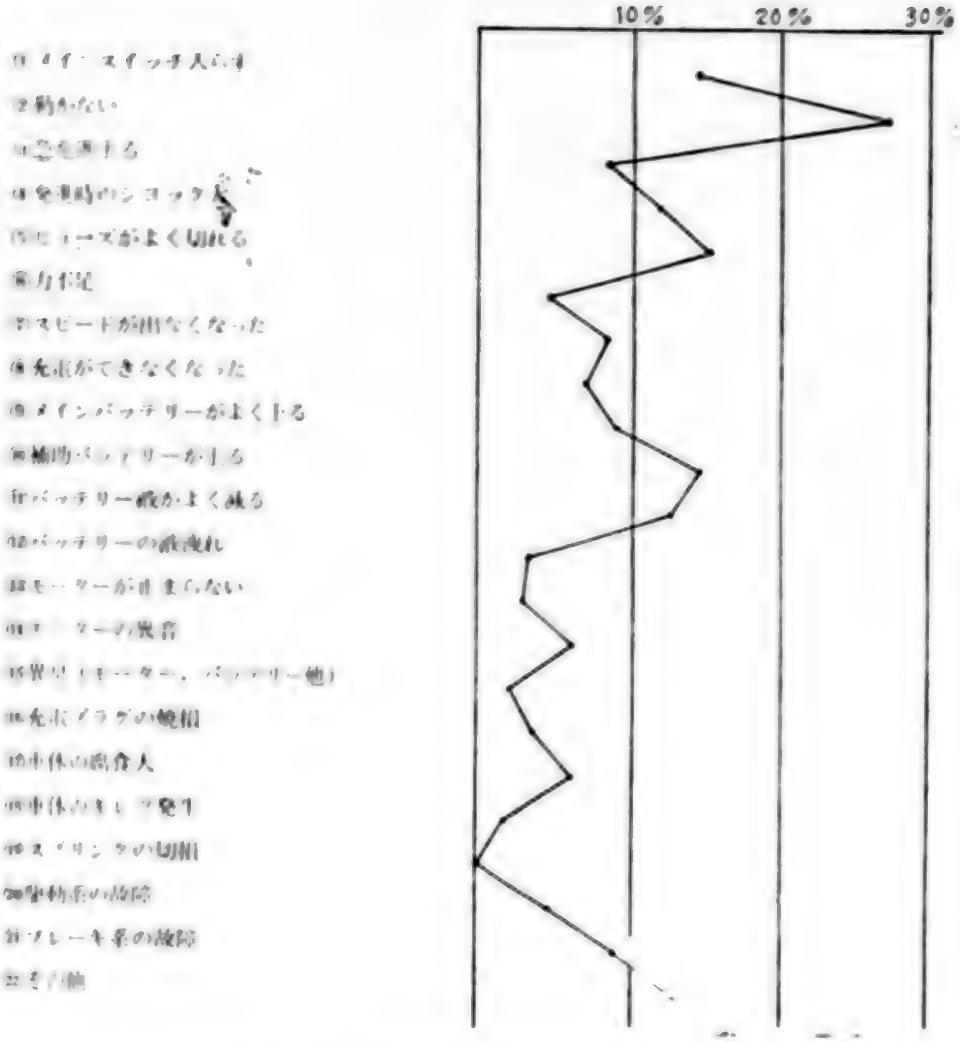

Figure 1. Trouble Emergence Status of Electric Automobiles

Key:

1. main switch ineffective
2. vehicle immobile
3. car makes quick starts
4. large shock on starting
5. fuse blows out often
6. lack of power
7. lack of speed
8. not chargeable
9. main battery fails often
10. auxiliary battery fails
11. battery liquid often runs low
12. battery solution leaks
13. motor does not stop
14. odd sound from motor
15. odd odors (motor, battery, etc.)
16. charging plug burns
17. high body corrosion
18. cracks form in body
19. spring breaks
20. troubles in drive system
21. troubles in brake system
22. other

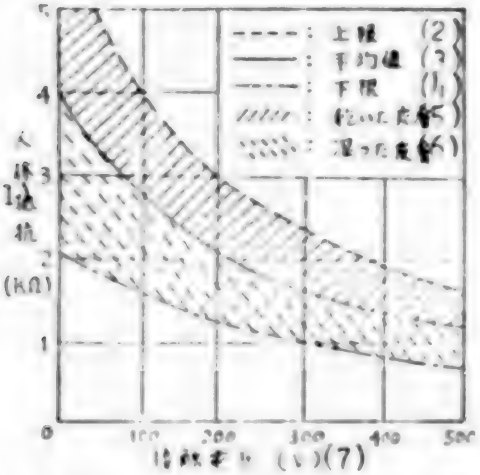

Figure 2. Relationship between Contact Voltage and Human Body Resistance

Key: 1. human body resistance 2. upper limit 3. average value
4. lower limit 5. dry skin 6. moist skin
7. contact voltage

(1) [illegible]	(2) 人体への影響	[illegible] (3)
(4) 1 mA[illegible]	[illegible] (5)	
1 ~ 3 mA	[illegible] (6)	(7) [illegible]
~ 5 mA	[illegible] (8)	
~ 10 mA	[illegible] (9)	(10) [illegible]
~ 20 mA	[illegible] (11)	[illegible]
~ 50 mA	[illegible] (12)	(13) [illegible]
~ 100 mA	[illegible] (14)	[illegible]

Key: 1. current at applicable frequency 2. effect on human body
3. name of current 4. less than 1 mA
5. a very sensitive person may feel this current
6. sensation of a very light stimulus 7. sensible current
8. sensation of some pain 9. nearly unbearable pain
10. disengageable current 11. muscles are paralyzed and limbs cannot be moved
12. somewhat dangerous
13. ventricular fine movement current
14. heart muscles vibrate in fine manner, this causes stoppage of blood to cells, and there is danger of death

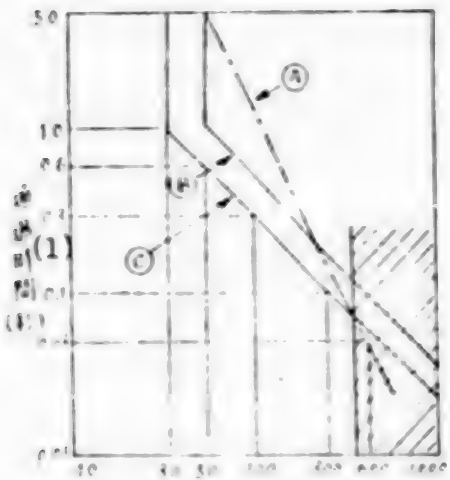

Figure 3. Electric Impact Time and Current Value

Key: 1. current passage time

Photo 1. Light Passenger Use Electric Automobile Model EV1 (Daihatsu)

Photo 2. Small Passenger Use Electric Automobile Model EV2 (Toyota)

Photo 3. Light Electric Truck (Toyo Kogyo)

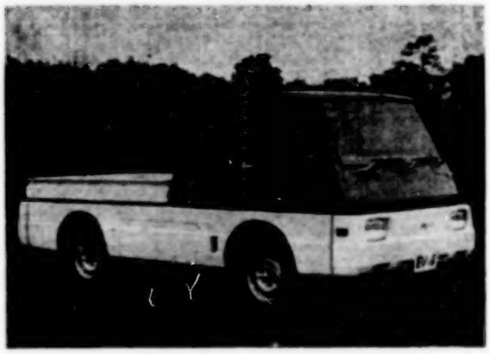

Photo 4. Light Electric Truck (Nissan)

Photo 5. Route Electric Bus (Mitsubishi)

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SCIENCE AND TECHNOLOGY

TOKYO: DEVELOPMENT OF ENERGY-SAVING HIGH-RISE BUILDING REPORTED

Beijing BEIJING RIBAO in Chinese 6 Nov 79 p 4

[Article by Luo Weilong [7482 3634 7893]: "Energy-Saving High-Rise Building"]

[Text] How to use waste heat for cooling and warming is a new effort on the part of Japanese construction engineers in recent years to save energy resources. At the present time there are more than 20 buildings in Tokyo alone that use this method to provide cooking and warming. Not long ago we visited such a building, the 22-level, "Shimbashi Towers."

This large building with a total area of 60,000 square meters depends entirely for summer cooling and winter heating on the recovery of waste heat within the building. This method effects a great conservation in fuel and reduces managements of expenses for this building.

"Shimbashi Towers" was built in July 1972. It has 5 levels underground, 15 levels above ground, and a 2-level tower-like structure atop the building for a total of 22 levels. The amount of waste heat radiated inside this building is vast. Principal heat sources include: 1) heat radiated by electronic computers, communications equipment and other machines located from the twelfth and the fourteenth floors; 2) heat radiated by the lighting and people's bodies; and 3) a large electric power transformer used in the supply of electricity to the surrounding area that is located on the fourth and fifth levels underground and which daily radiates a large amount of waste heat. Therefore, there is a great potential for the recovery of waste heat, accumulating it, and putting it to effective use.

The principles for the waste heat recovery system are largely the same as for any turborefrigerator with the difference being that the water circulating system in the condensor is divided into two parts. One part is connected to the circulating system of the cooling tower, and the other part is connected to the circulating system for warm air. The circulating process consists principally of first using a cold water pump to pump the cold water from the cold water tank into the rectifier where it goes through the rectifier's coiled tubing to recover heat from inside the building,

and is returned to the cold water tank. As a result, the temperature of the cold water in the tank gradually rises. When the thermostat in the coldwater tank discovers that the temperature of the water has risen, it switches on a heat pump, which absorbs the heat collected in the cold water tank for transport to a warm water tank where it is added to the water in the warm water tank. Once the heat in the warm water tank reaches its limit, the heat pump automatically shuts off.

The heat source machinery in "Shimbashi Towers" consists of two air heat pumps, two water-circulating heat pumps, one turborefrigerator, and three heat collecting tanks. All machines are automatically controlled by an electronic computer in a central monitoring room. They may be also controlled by humans. In Japan, consumption of electric power during daylight hours greatly exceeds consumption during the night. This building capitalizes on this characteristic in its management of heat resources by operating its heat source machinery at night to disseminiate heat in order to supply daytime use. During the daytime, the heat source machinery is operated as little as possible. The heat collected each night is used up entirely during the following day.

By way of using the energy of the high rise part of this building to return the original water, they have used the building as a revolving motive power to drive the pumps in order to reduce the load on the circulating pumps. Japanese friends call this sytem a "motive force recovery installation." The recovery rate of this installation is between 30 and 40 percent.

This building contains an almost perfect hot water supply system. Except for the night time use of electric power to operate the electrically heated warm water device, hot water is supplied by waste heat recovered from the rectifier. The hot water supply system within the building is divided into an upper and a lower part. The fifteen levels above ground and the machine rooms on the three levels below ground have separate warm water devices heated by electricity.

"Shimbashi Towers" is but one of the numerous buildings in Japan that conserve energy resources. Japanese construction engineers are working on further new ways to conserve energy resources. The building to house the Kosaki branch of the Central Region Electric Power Company, which was built in May of this year, contains further energy saving features. As compared with large buildings of the same scale that were built in the past, it has about 40 percent more energy saving and that attracts people's notice.

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